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# A Novel Design of a Fractal Antenna for IMT and WiMAX Applications

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***Abstract*-In this paper, a new planar monopole antenna is designed and fabricated for IMT and WiMAX applications. The antenna is based on the use of Sierpinski triangle with a modified ground structure consisting of T-shaped and small rectangular slots printed in the ground. The entire area of the proposed antenna is 55x50mm$^2$ and it is printed on an FR-4 epoxy substrate and fed by a 50 Ohm microstrip line. This new design helps in enhancing both the reflection coefficient and the bandwidth. The electrical performance of the fractal antenna is investigated by the use of CST-MW and HFSS. The simulated results present good performance in terms of matching input impedance and radiation pattern. The electromagnetic results of the fractal antenna are in a good agreement with measurement results.**

***Index Terms*- Fractal antenna, IMT-band, WiMAX band, Modified Ground Structure, Sierpinski triangle, CST-MW, HFSS.**

## I. INTRODUCTION

Due to the progress that has been made in the field of wireless communication systems, there is a need for antennas with vital requirements such as small size, lightweight and good performance. This has also led to an interest to improve the performance of antennas that can operate with multiband frequencies such as the global system for mobile communication (GSM), digital cellular system (DCS), global positioning systems (GPS), Wireless local area network (WLAN) which has made rapid progress and several IEEE standards are available namely 802.11a/b/g/j, universal mobile telecommunications System (UMTS), IMT advanced system or fourth generation mobile communication system and the worldwide interoperability for microwave access (WiMAX) [1-6]. Recently, fractal concept has been introduced with the aim of improving and achieving the multiband behavior of antenna. The term fractal geometry, which was originally coined by Mandelbrot, refers a family of complicated forms that have self-similarity in their geometrical structures. In fact, the fractal geometry is supported by two characteristics: self-similarity and space filling. The self-similarity property is practical for multiband feature while space filling property is useful for antenna miniaturization [7-8]. In literature, fractal antennas offer many advantages: ability to achieve multiband frequency response, good broadband for each resonant frequency, compact size, mechanical simplicity and robustness. Other advantages include ease of integration with other types of microwave integrated circuits and the ability to be used for both linear and circular polarization. However, fractal antennas present some limitations such as Low gain, complex geometry; numerical limitations and practically few possible iterations [9].

Fractal antennas can come up in many geometries. These include sierpinski gasket, sierpinski carpet and Koch curves [10-13]. We can also use another method to miniaturize and to improve the bandwidth and reflection coefficient for multiband antennas by using the modified ground structure [14-15].

In this article, a novel fractal antenna with modified ground structure is presented. The antenna structure comes in the form of a Sierpinski triangle within a rectangle and a modified ground structure consisting of T-shaped and small rectangular slots are printed in the

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ground. The purpose of this structure is to miniaturize and enhance the bandwidth and reflection coefficient for dual band antennas. The proposed antenna can be tuned to operate in the following bands: IMT advanced system or fourth generation mobile communication system and Mobile Worldwide Interoperability for Microwave Access Mobile WiMAX. The fractal antenna is initially designed and simulated by using the finite integration time (FIT) introduced in CST-MW and verified with another electromagnetic solver HFSS, then fabricated to confirm the simulation results.

## II. FRACTAL GEOMETRY

In literature, many fractal geometries are used to obtain the multiband behavior. We can find Cantor set geometry which is based on the following algorithm shown in Fig.1. It starts with the closed interval [0, 1].


Fig.1. Generation of cantor set geometry

The use of Sierpinski gasket geometry is another technique to obtain the multiband function. The steps for constructing this fractal are shown in Fig.2. The Sierpinski gasket fractal is achieved by performing the iterative process. This process can be done for an infinite number of times until we obtain the desired geometry [16].

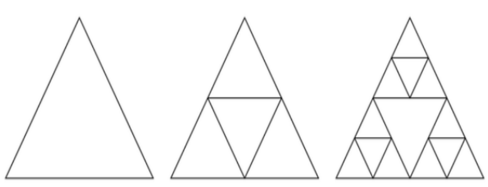


Fig.2. Generation of Gasket geometry

Another geometry which is widely used to obtain the multiband behavior is the use of Minkowski fractal antenna as shown in Fig.3 [17-18].

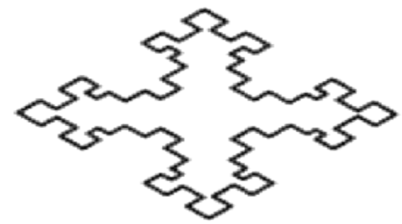

Fig.3. Minkowski Fractal structure

## III. ANTENNA DESIGN

The structure of the proposed antenna is realized in many steps. First, a simple cut-corner rectangle microstrip patch antenna and a feed-line are printed on the top layer of a substrate FR-4. This latter has the following characteristics: Dielectric constant εr = 4.4, substrate thickness h=1.6 mm, loss tangent tan (δ) = 0.025 and metallic thickness of t=0.035 mm. This antenna is fed by a microstrip line with 50Ω characteristic impedance as shown in Fig.4.


Fig.4. Simple cut-corner rectangle microstrip patch antenna

Then, Sierpinski gasket geometry is used to increase the gain and achieve multiband behavior. Fig.5, presents the proposed Sierpinski triangle multiband antenna with different scale factors (δ1=h1/h2, δ2=h2/h3, δ2=h3/h4) as mentioned in [19]:

$$\delta = h_n / h_{n+1} \tag{1}$$

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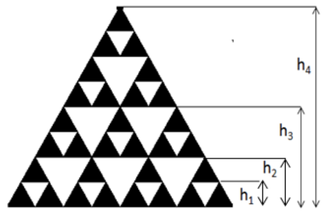


Fig.5. Geometry of Sierpinski gasket

Where n is the iteration number and h is the height of the triangle.

Finally, T-shaped and small rectangular slots are printed on the ground as shown in Fig.8. These slots help in reducing the overall weight and the size of the proposed antenna. Fig.6 shows the steps followed to design the proposed antenna.

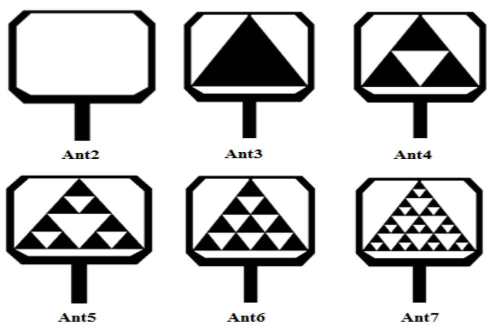


Fig.6. Steps followed to develop the proposed fractal antenna

After designing the antenna as shown in Fig.4 and Fig.6, we have obtained different reflection coefficients |S11|/dB corresponding to each antenna from Ant1 to Ant7 as shown in Fig.7.

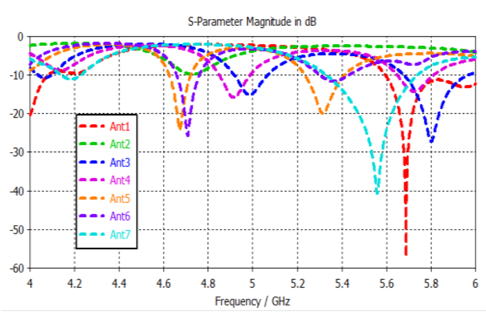


Fig.7. Different |S11|/dB versus frequency obtained for each antenna

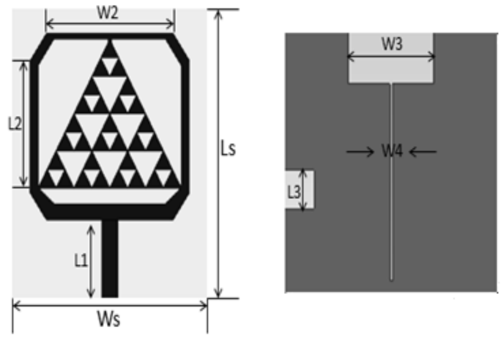


Fig.8. Geometry of the proposed antenna

After many optimizations, the final antenna is validated with the parameters shown in Table 1. The total volume of the proposed antenna is (55x50x1.6) $mm^3$.

Table 1: Dimensions of the proposed antenna (Unit: in mm)

| Parameter | Value | Parameter | Value |
|---|---|---|---|
| Ws | 50 | W4 | 1 |
| Ls | 55 | L1 | 25 |
| W2 | 15 | L2 | 8 |
| W3 | 32 | L3 | 20 |

As depicted in Fig.9, we have obtained an optimized antenna with the first resonant frequency of 4.2 GHz and a bandwidth (4.130-4.241GHz), that can be suitable to the IMT band .The second resonant mode occurs at the frequency of 5.6 GHz with a bandwidth (5.313-5.752GHz), which covers the WiMAX band.

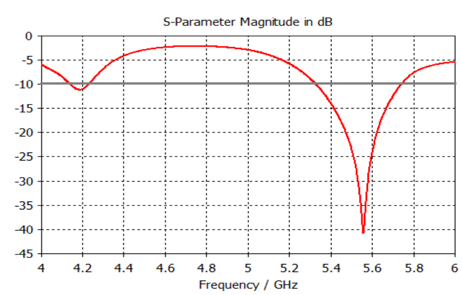


Fig.9. Reflection coefficient vs frequency of the proposed antenna on CST

In order to check the results given by CST-MW, it was necessary to use another electromagnetic

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solver HFSS. From Fig.10, we conclude that the two solvers are in a good agreement as far as reflection coefficient is concerned [20].

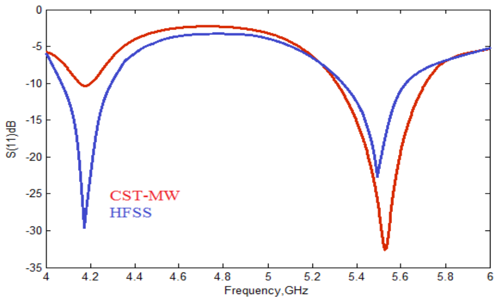


Fig.10. Comparison of reflection coefficient |S11| between CST-MW and HFSS

The electrical-field distributions of the fractal antenna at 4.2 GHz and 5.6 GHz are shown in Fig.11. Fig.11 (a) depicts electrical-field distribution at 4.2 GHz. The concentration of the current is at the feeding line and the lower part of the antenna. Fig.11 (b) presents electrical-field distribution of the fractal antenna at 5.6 GHz. The current is heavily concentrated at the feeding line, the lower part of the cut-corner rectangle antenna and in the middle of the sierpinski gasket.

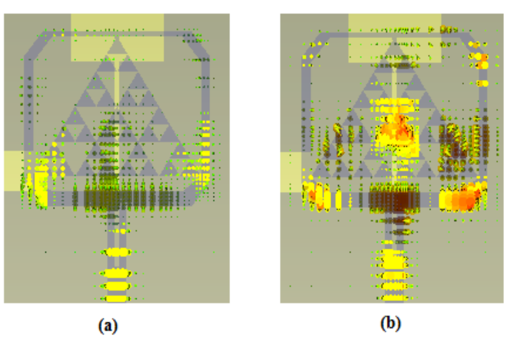


Fig.11. Electrical-field distributions of the proposed antenna at: (a) 4.2 GHz (b) 5.6 GHz

The simulated Far-field radiation patterns in CST-MW for the three resonant frequencies are shown in Fig.12. According to this figure, the antenna becomes quasi-omnidirectional and stable radiational at the following resonant frequencies: 4.2 GHz and 5.6 GHz.

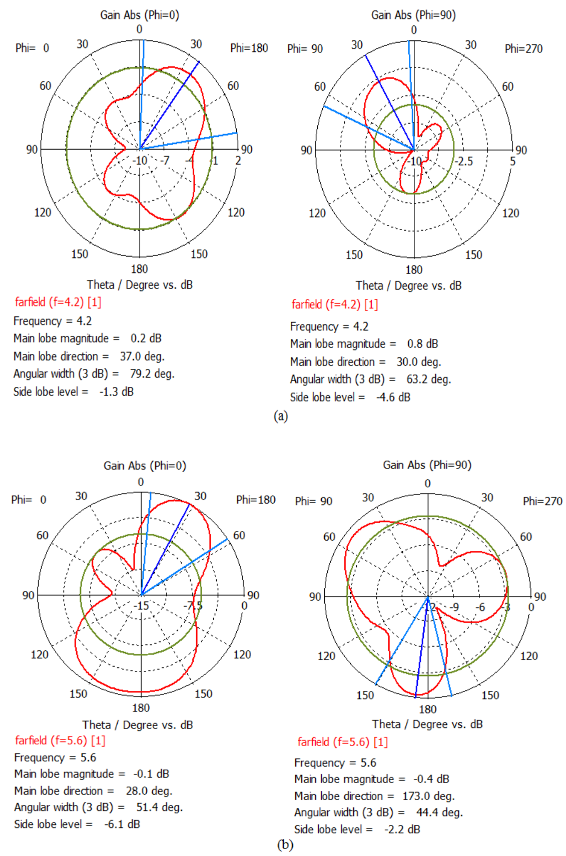


Fig.12. Radiation pattern of the proposed antenna in CST: (a) 4.2 GHz (b) 5.6 GHz

From the plot in Fig.13, we notice that the VSWR (voltage standing wave ratio) maintains the value of less than 2 at the frequency range of (4.129-4.244 GHz) and (5.313-5.752GHz).

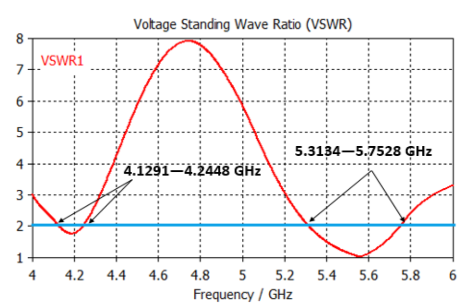


Fig.13. VSWR Vs frequency

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Fig.14, presents the variation of the gain versus frequency. We have obtained the gain of 0.882dB and 2.108dB that corresponds to 4.2 GHz and 5.6 GHz frequency respectively.

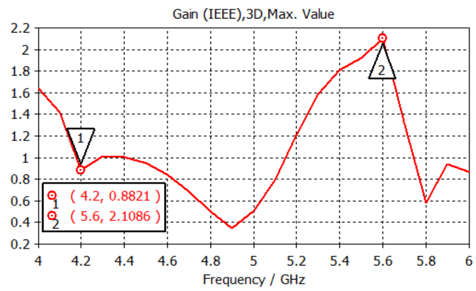


Fig.14. Gain Vs frequency

Table. 2 presents a comparison of the proposed antenna with bibliography while taking into account the antenna size, return loss, reflection coefficient and antenna purpose. As we can see from the same table that the proposed antenna is smaller in terms of size and suitable for dual-band applications.

Table 2: Comparison of the proposed antenna performance with other compact antennas

| Published literature versus proposed work | Antenna Size ($mm^2$) | Return loss S(1,1) dB | Reflection coefficient (GHz) | Antenna purpose |
|---|---|---|---|---|
| Ref[21] | 53.37x75.20 | -17.2 | 1.8 | Tri-bandes |
| | | -22.5 | 3.5 | |
| | | -35 | 5.2 | |
| Ref[22] | 120x120 | -28 | 0,98 | Dual-band |
| | | -14 | 1.84 | |
| Proposed work | 55x50 | -13 | 4.2 | Dual-band |
| | | -40 | 5.6 | |

## IV. EXPERIMENTAL RESULTS AND DISCUSSION

The proposed circuit is fabricated as shown in Fig.15, on the FR4 substrate, the measurements have been performed by using Rohde & Schwarz Vector Network Analyzer (R&S ZVA-40). The circuit size is relatively small, with an area nearly equal to ($55x50mm^2$).

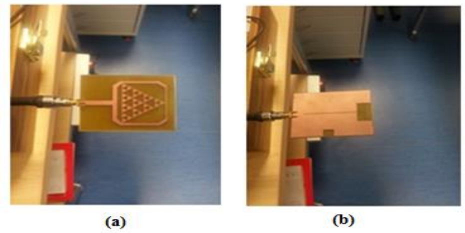


Fig.15. Photo of the fabricated antenna structure (a) top face (b) back face

After testing the achieved antenna, we have conducted comparison between simulation by CST-MW and measurement results as shown in Fig.16.

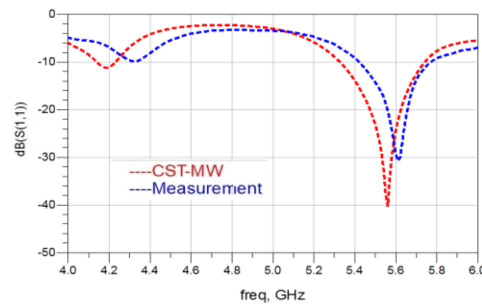


Fig.16. Comparison of simulated and measured reflection coefficient versus frequency

In Fig.16, we notice that there is a close agreement between simulation and measurement results. This slight difference between the measured and simulated results is due to the fabrication constraints, uncertainty in the dielectric constant, substrate thickness and soldering effects.

## V. CONCLUSION

In this study, a novel cut-corner microstrip fractal antenna with T-shaped and small rectangular slots in the ground plane has been designed and fabricated for dual band. The objective of this new design is to improve the bandwidth and the resonant frequencies for each band. This antenna has been designed and optimized by using CST-MW. The achieved and tested cut-corner microstrip fractal antenna presents close

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agreement between simulation and measurement results. The measurement results show that this new compact size dual band antenna structure is suitable for IMT (4.130-4.241GHz) and WiMAX (5.313-5.752GHz) frequency bands. The antenna has positive properties such as compact size, lightweight, low cost, simple to fabricate and easy to be integrated with passive and active elements.

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